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Fractal Geometry Tools in Studying the Formal Characteristics in the Urban Structure of the Traditional Al-Mutanabbi Street in Baghdad

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ABSTRACT

The research focuses on examining the level of harmony in the formal characteristics among the elements of the traditional Baghdad alley, from individual components to the entire area. Numerous studies have highlighted the unity and cohesion in the urban structures of traditional Arab urban environments, including Baghdad alleys, despite the diversity of the urban landscape. The study's theoretical aspect focuses on the visual features of the traditional urban environment, emphasizing the concept of diversity within unity. This is explored through specialized studies in the field. The applied part of the study involves using fractal geometry tools, specifically the box-counting method, to measure the degree of harmony and variation within different parts of the urban environment. This assessment starts from individual parts and expands to the panorama on both sides of the alley. This research aims to highlight the visual characteristics of traditional alleys that are essential to their urban framework. It is imperative to incorporate these characteristics into new urban plans to effectively uphold the local identity. The research problem is the lack of studies on fractal geometry as an analytical tool for designers to achieve specific formal characteristics, such as harmony between parts and the whole, particularly in the context of traditional paths. The research took into account the historical, social, and cultural influences on urban design in Al-Mutanabbi Street. The findings revealed that these influences significantly shape the urban framework and enhance the cohesion among different elements.

Keywords: Fractal geometry, Urban environment, Al-Mutanabbi street, Harmony, Unity.

1. INTRODUCTION

Computer programs play an integral role in shaping various aspects of our daily lives, including education, communication, entertainment, business, and healthcare **(Zarzoor et al., 2023).** Fractal geometry, an application of computer programs, is essential for studying the relationship between different parts and the entirety of urban structures. It focuses on the balance between unity (homogeneity and integration) and diversity (contrast and

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variation) within these parts. To achieve urban aesthetics and visual comfort, it is necessary to find a balance between these two elements **(Batty and Longley, 1994; Madkour et al., 2023).** Unity in the urban structure includes organizing many different elements in a way that enhances integration and homogeneity. At the planning level, the arrangement of buildings, shops, services, and public spaces is considered one of the fundamental elements for achieving unity **(Lynch, 2023).** The 1994 Nara Document on Authenticity emphasized the importance of the integration of the whole and the part, as a part of cultural heritage cannot be separated from the broader context to which it belongs. In other words, the individual parts of heritage must be understood in their entirety, with each part interacting with the others to form the complete picture of the heritage **(Deacon and Smeets, 2013).** Unity is attained by the use of common architectural elements, repeated geometric designs, harmonious colors and materials **(Alexander et al., 1979).** Meanwhile, diversity is attained by the use of diverse architectural elements, unique designs, and different colors and materials. Achieving an equilibrium between unity and diversity is one of the main aspects that affect the harmony of societies, and fractal geometry tools, which are effective for studying this interaction and harmony between the different elements in the urban structure **(Bovill, 1996)**.

Fractal geometry is valuable in spatial analysis and offers a new perspective on urban and regional systems. Cities can be observed as fractal systems with self-similar properties, which makes them suitable for fractal analysis due to the gradual influence of local factors making organized urban patterns **(Badiei et al., 2021)**.

Fractal geometry includes complex shapes that exhibit self-similarity at different levels. The fractal dimension, which ranges from 0 to 2, offers a unique way to imagine and analyze urban environments comprehensively. It reflects the irregularity, complexity, and self-similarity of spatial patterns such as coastlines and vegetation. This makes fractal geometry an brilliant tool for assessing dynamic urban growth, the progression of urban form, and the spatial organization of physical features **(Rakibuzzaman and Islam, 2022)**.

Any architectural product can consider to have fractal properties if it has a fractal dimension. This valuation is based on some structural mechanisms, such as integration and multiplicity, self-similarity, interconnected hierarchy, and growth across time and space. Research has shown that including fractal dimensions into architectural products causes greater harmony with nature, which shows similar characteristics in its complex system **(Al-Dabbagh and Ismail, 2024)**. Fractals used to analyze urban forms as represented by built-up area patterns, urban limitations, and other structural elements of the city such as transportation networks, etc. The relatively homogeneous distribution of built-up areas leads to linear/disparate/fragmented development patterns leading to lower fractal dimension values, which is an indicator that captures some of the characteristics of the complexity of urban development patterns **(Lagarias and Prastacos, 2021).**

The unit in urban structure includes many different elements that are organized and grouped in a way that promotes integration and homogeneity. The integration of the formal structure of urban centers in traditional cities is achieved by reorganizing the elements of its physical structure by achieving the concept of gradation of functional movement patterns. This requires fixed, controlled boundaries for the urban center and a functionally adapted and formally distinct urban pattern **(Rasheed and Salman, 2018)**. The comprehensiveness of urban integration is achieved through the application of four characteristics: accessibility, affordable housing, resilience, and sustainability **(Asian Development Bank, 2017)** The concept of integrated urbanization is an important indication of a more sustainable urban

environment through five basic characteristics of integration: hybridity, connectivity, porosity, authenticity, and vulnerability **(Ellin, 2006)**. Urban integration as a systemic behavior of the city as a system consisting of several secondary systems linked by relationships that result in the final form of the city, making it a comprehensive system. These secondary systems include the physical system, the movement system, the cognitive values system, and the production system, and represent the nature of diversity and specialization in the division of production in urban society **(Rasheed and Salman, 2018)**. This study aims to evaluate the degree of visual harmony in the urban structure of the traditional Baghdad alley using fractal geometry tools and aims to explore these tools to study the harmony between the part and the parts in the urban structure of Al-Mutanabbi Street. The study takes into account the specificity of the historical factor in the architectural and urban design of the street, in addition to the social and cultural factors that affect the formation of the urban structure and enhance the balance between the different elements. Some studies indicate that the success of a building is achieved through its ability to make a positive contribution to the urban space, and planners and designers often use the term "active facades" to describe the positive relationship between the building and the urban space. Considering that the urban environment is a group of buildings that were created within an urban space that can affect human behavior, happiness and level of satisfaction **(Al-Mousawi et al., 2023)**.
Here lies the importance of the study of Al-Mutanabbi Street as an influential urban heritage environment in Iraqi society in particular.

2. PREVIOUS STUDIES

(Cagdas et al., 2005) highlighted a significant challenge in architectural design, which is to create a balance between old and new elements. Fractal concepts have been utilized in various ways, whether intentionally or unintentionally, in the realm of architecture. The study focused on Kariye Bostani Street in Istanbul as a representative example, chosen for its traditional architectural characteristics. The street features multi-storey and low-storey buildings with traditional Ottoman architectural style. In spite of efforts to preserve the street's pattern, the effect of the surrounding chaotic architecture is still seeming.

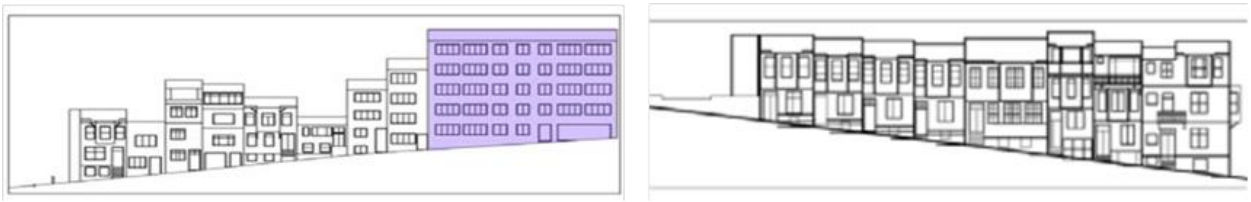

Figure 1. Kariye Bostani Street in Istanbul **(Cagdas et al., 2005)**.

In this study, a generative design approach was proposed that depend on the fractal dimensions of an existing architectural pattern. This approach support creativity in producing new forms and testing the harmony between the old and new. By employing the fractal dimensions of the elements in the form library related with a specific architectural language, this technique may guide the creation of architectural forms that keep the continuity of the pattern. The research employed digital techniques through the conceptual design phase to explore different forms, representing a new approach that depend on the

development of innovative technologies. Apply digital media as a design tool permits designers to increase their creativity and foster new ideas. By including alternative three-dimensional forms into the model, the research tested their compatibility with the current architectural language.

(Al-Askary and Al-kaissi, 2016) discussed some significant perceptions, with visual integration being the most important. This perception represents the general composition consisting of an interconnected system of relationships that connect the parts and the whole. It also organizes the components of urban structure in a city, crystallizing the integrated urban and sensory image of the relationships between visual characteristics, thus giving the city its distinctive urban identity and character. The study indicates that visual integration is accomplished through formulas linking visual elements and characteristics. This occurs at both the individual and overall level and is associated with visual relationships within design principles. This is particularly important for achieving the overall visual composition, especially in historical city centers. The study also addresses two types of factors that impact the urban scene: physical factors and human factors. When integrated, these factors achieve visual unity. Additionally, the study identifies two levels to achieve visual unity of the urban scene: relationships at the overall level ("general formation") and relationships at the level of individual parts (the relationship of one part with another within a single shape and its visual relationship with parts of neighboring shapes). These parts include building elements such as openings, architectural details, or the size of a single building as a single block, especially in comparison with neighboring ones.

According to **(Meshal and Alomari, 2019),** the study focused on the pleasing effects created within a space by the structural layout and original lines. These elements were identified by their unity and rhythmic repetition, achieved in various ways. The study also highlighted that the diverse formal aspects of Islamic architecture are governed by the principle of similarity. This means utilizing units that share a general shape without being identical in size and composition. The aim is to establish a concealed hierarchy through a series of transformations. The author emphasized that unity involves bringing things together to create a cohesive whole, providing a comprehensive and unfragmented perspective. The composition is seen as an integrated whole, and the most important relationships through which the unity of composition can be achieved are repetition, similarity, symmetry, and proportionality of parts to each other. Unity often involves diversity to give the design essential characteristics, as unity in its abstract and condensed form can lead to a lack of interest, while diversity without unity can lead to chaos. Furthermore, the concept of unity is expressed through the gradation in the sizes of the elements, and the detailed treatments they undergo, in addition to their adherence to certain proportional systems. Therefore, the physical shapes and their relationships are an effective means of creating formal cohesion, which is one of the most interesting aspects of the human brain. The study identified mechanisms for achieving formal unity, including organization of structure elements to achieve unity and coherence, such as inclusion, symmetry, hierarchy, repetition, complementary elements, proportion, the nature of the treatment itself (decoration, texture, material), fusion, and similarity**.**

(King, 1988) study delved into the visual characteristics of the urban environment and the role of architectural design in addressing them to create an urban environment that meets the diverse needs of its users. Bently identified these characteristics as (clarity, diversity, permeability, durability, visual suitability, and richness). He underscores the significance of the urban designer's role in quantifying these characteristics in the built or designed

environment, thereby ensuring that architectural and urban spaces are attuned to the sensory experiences of their inhabitants.

In **(Al-Muqrim, 2013)** study, the focus was on identifying the positives and negatives in proposals for developing old city centers, specifically in Kadhimiya and Najaf, in line with the traditional Arab city design standards. This was achieved by analyzing traditional Arab cities using fractal geometry tools to illustrate their close relationship with various characteristics such as structure, human scale, cohesion, hierarchy, self-similarity, hierarchical association, complexity, diversity, order, meeting surfaces, folded lines, perforated areas, and mechanisms of repetition and interaction. The study's most significant findings suggest that all traditional Arab cities exhibit fractal characteristics. These cities are distinguished by their integrated structure, comprised of cohesive and interconnected secondary structures governed by a latent system where the whole controls the parts. The human scale is evident in both horizontal plans and facades and encompasses complexity, self-representation, diversity, and a hierarchical scale that connects all parts. Additionally, clear meeting surfaces determine the movement and interaction of residents and strangers, displaying folded, winding, and perforated surfaces between buildings and alleys, as well as repetitive residential units. Moreover, the traditional fractal city includes secondary structures, such as residential units surrounding religious buildings that expand outward**.**

Previous studies can be classified in part as descriptive studies that discuss the concepts of unity and diversity, both of which are essential features of the traditional urban environment. Other applied studies deal with measurement mechanisms. Unity includes coherence and harmony between the different components, while diversity is evident in the visual panorama and the variety of elements within a coherent formal unit. From previous studies, some indicators can be extracted for use within the program's measurement mechanism, such as:

- Repetition
- Hierarchy
- Harmony
- Diversity
- Symmetry
- Similarity
- Richness
- Visual suitability
- Visual coherence

Fractal geometry has employed these indicators as tools to measure the extent of harmony and cohesion, aiding in achieving an integrated unity within the architectural system. These methods function to connect different parts of the design within a complex structure, where all components share formal characteristics that contribute to coherence and harmony, making them appear as part of a single, integrated, and harmonious architectural system.

Consequently, we can define the research framework that engages fractal geometry as a tool for analyzing architectural products, with the aim of assessing the variation in harmony and cohesion of parts within the urban structure, within the context of Al-Mutanabbi Street as an applied study.

3. METHODS AND MATERIALS

Many researchers have used the fractal dimension analysis method, where they used fractal analysis to describe the complexity of urban skylines and nature, and investigated fractal

dimensions in relation to urban design qualities and urban character **(Cooper, 2005; Cooper and Oskrochi, 2008; Çobanli, 2024).** This method was built on the research of **(Mayatskaya et al., 2024; Bovill, 1996)** who proposed the use of the square-counting (DB) dimension method to determine the fractality of architectural design. This fractal dimension is a numerical quantity that indicates the extent of which the fractal fills the space, as it is enlarged to finer scales **(Lu et al., 2019)**. Fractal dimensions were shown to be robust indicators of urban morphology, with potential applications in urban planning and simulation. They reveal hierarchical and nested spatial structures **(De Keersmaecker et al., 2003)**

The box-counting method has broadly been used for architectural and urban analysis. For example, urban forms, street patterns, and city skylines have been repeatedly described or analyzed using this method **(Ostwald, 2013; Liu and Chen, 2022)**. This method is proposed to determine the fractal dimension of a complex two-dimensional image. First, a grid of squares is created on the image of the selected shape at a certain hierarchical scale, the number of boxes containing lines and details is counted, and the steps are repeated on different grid sizes according to the selected hierarchy **(Almoqaram, 2008)**.

Here, the standard Image equipped with the FracLac plugin is a public domain program written in Java and it is a commonly used tool for fractal analysis, it was used as the fractal dimension estimator, a publicly available plugin that analyzes binary and/or grayscale images of an image **(Lagarias and Prastacos, 2021; Konatar et. al., 2020)**.

To calculate fractal dimensions by a box-counting method, allowing one to perform a fractal analysis of building projections **(Bisoi and Mishra, 2001; Karperien, 2007).** When analyzing complex images that other traditional methods cannot describe, DB simplifies how to find the fractal dimension of complex images. The idea behind this method is the degree of "roughness" and "irregularity" of the structure, which in turn reflects the complexity of the object **(Shishin and Ismail, 2016).**

The method is used as follows: A grid of a certain size (S1) is imposed on the image and the number of cells that include the image details, which can then be calculated (N for s1). The size of the grid (S2) is then reduced, and the number of cells (N for s2) is again calculated.

The fractal dimension between two scales is then calculated by relating the difference in the number of occupied boxes to the variance of the inverse grid sizes. The calculation can be expressed mathematically by Eq. (1) and Eq. (2).

$$DB(1-2) = [\log N\,(s2) - \frac{\log(\,s1)}{\left[\frac{\log 1}{s2} - \frac{\log 1}{s1}\right]} \tag{1}$$

Or

$$DB(1-2) = \frac{\left[\frac{log\ N\,(s2)}{N(s1)}\right]}{\left[\frac{log\ 1}{s2}\right]} \tag{2}$$

Where S represent the grid size, and N represent the number of cells overlapping the image details **(Bovill, 1996; Mayatskaya et al., 2024)**.

The procedure of the method used in this study will be as follows:

For an additional objective analysis of the consistency between two levels of fractal graphs, the correlation or "CORREL" function in Microsoft Excel will be used.

The equation of the correlation coefficient is as follows:

$$CORREL(X,Y) = \frac{\sum(xx-)(yy-)}{\sqrt{\sum(xx-)2\sum(yy-)2}} \quad (3)$$

Where x- and y- are example values for X (array1) and Y (array2) ("AVERAGE" (array1) and "AVERAGE" (array2) in Microsoft Excel (2016).
This function displays the level of correlation between the graphs of several data sets. Here, the nature of the fractal dimension at different scales (which can usually be clearly seen in the graphs) is very important for comparing the fractal coherence between different projections of the building **(Shishin and Ismail, 2016)**.
The research methodology includes both quantitative and qualitative methods. The quantitative values are represented by the fractal dimension within the calculations of the box-counting method, and at the same time, these values represent the qualitative characteristics of the urban environment. The research boundaries in the practical part include the general urban level, leaving the scope of studying the architectural level for future studies.

3.1 Case Study (Al-Mutanabbi Street)

Heritage represents all that our predecessors have left behind, and it should be safeguarded through restoration or preservation to ensure its transmission to future generations. It is worth lies in the various aspects of historical, archaeological, architectural, technical, aesthetic, scientific, spiritual, and social significance related to human activity **(Hussein and Ismaeel, 2021; Abdulrahman and Al-Allaf, 2023)** Al-Mutanabbi Street, previously known as Al-Akmakhana Street, is situated between the Tigris River and Al-Rashid Street and dates back to the Ottoman era.
Al-Mutanabbi Street contains iconic buildings such as the Saray Building and Al-Mustansiriya School, which give it a unique historical character. It was a center of cultural culture, with a strong impact on the urban scene as a link between social celebrities. Due to its association with libraries and cultural cafes, which were part of the social structure of the city .Historical factors were reflected in some elements, such as the use of decorative bricks, arches, and military elements from the local heritage. Commercial activities on the street have played a major role in shaping its urban pattern and continuing its use as a social and cultural center. This street is renowned for its diverse architectural styles, blending contemporary additions with original designs. Following the destruction of Al-Mutanabbi Street, new architectural features were introduced as part of development projects. Despite some buildings that may disrupt the street's visual coherence, they share common characteristics that contribute to a connected and historically significant streetscape. Al-Mutanabbi Street experienced a terrorist attack that resulted in the destruction of a significant portion of it. This incident required the Street to undergo rehabilitation, including the transfer of its undamaged architectural elements, in order to preserve the area's urban identity and historical character while integrating new urban developments. The development process of Al-Mutanabbi Street, as shown in **Fig. 2**, involved the use of modern techniques that resulted in changes to the skyline and the surrounding area. Some buildings now reach up to 6 floors using concrete and structural systems. Despite this, the outer facades of the buildings still attempt to imitate the old style of the historical center, although with some differences in details. As a result, the new structures blend in with the existing architecture, maintaining similar levels of protrusions and porticos. However, regrettably, the character of this axis no longer exhibits its Ottoman and Abbasid style through the use

of construction and finishing materials other than brick **(Rasheed et al., 2023)**. The research concentrated on Al-Mutanabbi Street, where restoration utilized original techniques to preserve its architectural and heritage features.

Figure 2. Recent Images of Al-Mutanabbi Street.

4. RESULTS AND DISCUSSION

4.1 Data Analysis and Results

The facades of Al-Mutanabbi Street are analyzed at two levels (the whole, and the parts)

- At the first level: involves analyzing the Al-Mutanabbi Street panorama at a general level and on both sides of the path, in Panorama zones (A) and (B), as shown in **Fig. 3.**

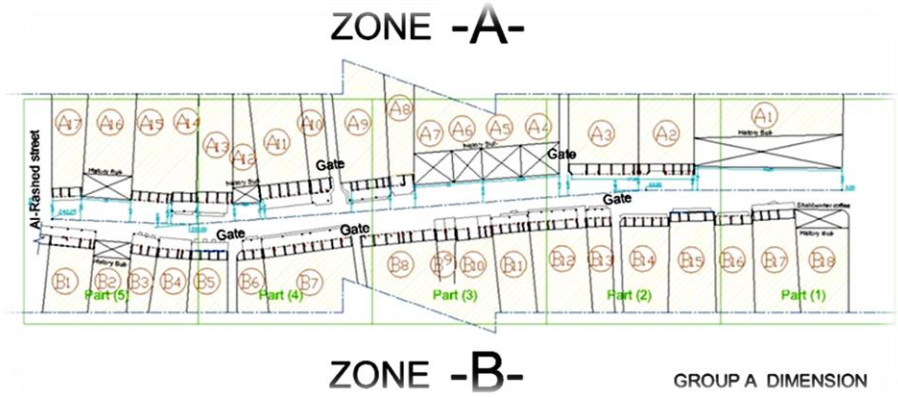

Figure 3. Al-Mutanabbi Street plans show the division of the street into two parts, Zone A and Zone B.

The process begins by drawing the facades in the AutoCAD program **(Figs. 4 and 5)**, followed by inputting them into the ImageJ program. After adjusting the program settings and selecting the Box counting method, the size of the networks to be analyzed is determined. The sequence of networks analyzed is as follows: (8,16), (16,32), (32,64), (64,128), (128,256), and (256,512). Analyze the Panorama (Zone A) and calculate the fractal dimensions based on the grids mentioned above, as shown in **Table 1** and **Fig. 6**

Figure 4. Panorama of Zone A.

Figure 5. Panorama of Zone B.

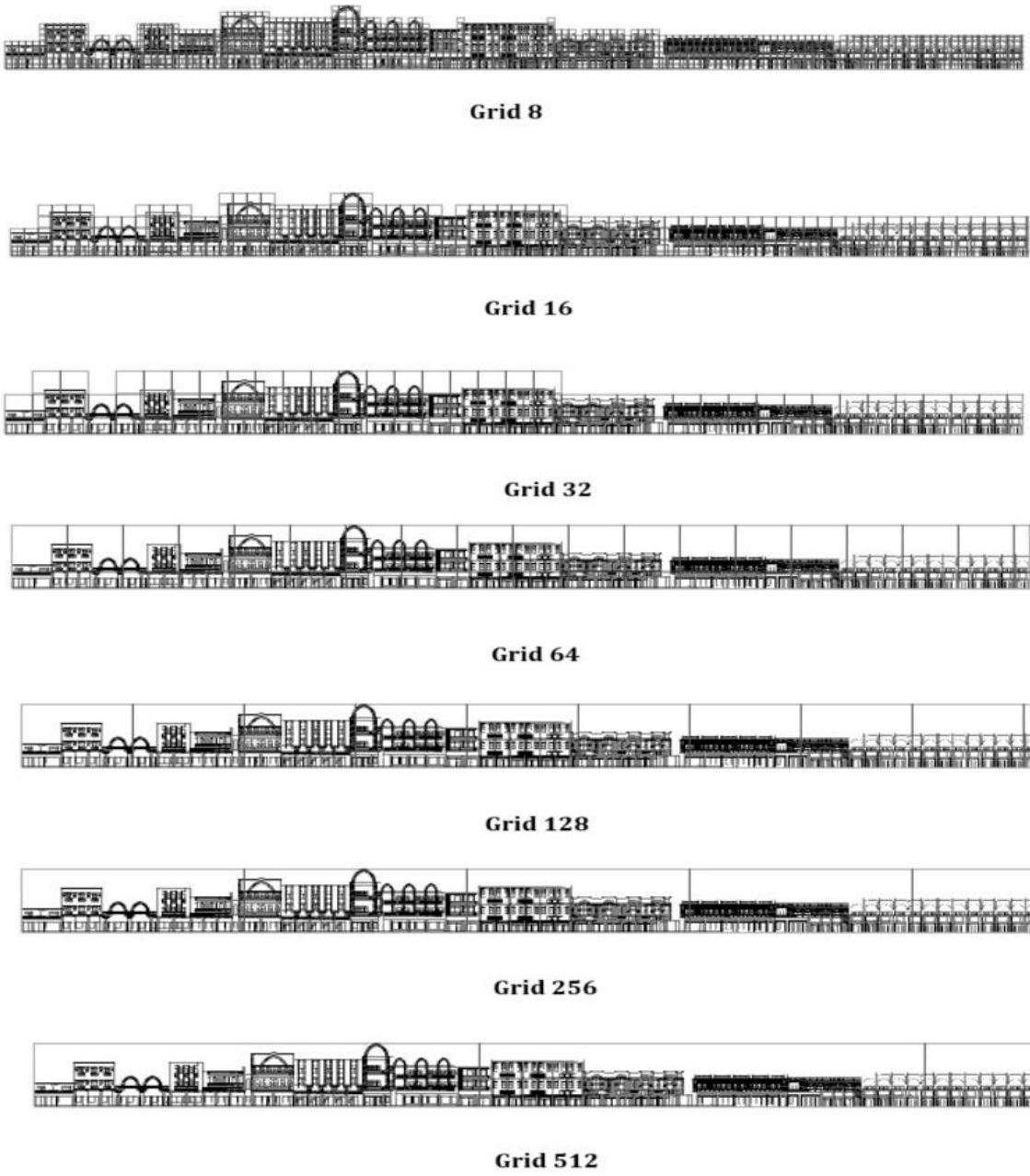

Figure 6. Analysis panorama of the zone A in grids (8,16,32,64,128,256,512)

Table 1. Fractal dimensions of zone A according to the grids

Zone A	
Grid	**Fractal dimension**
8,16	1.6568
16,32	1.8558
32,64	1.2756
64,128	1.926
128,256	1
256,512	0.737

Analyze the Panorama (Zone B) and calculate the fractal dimensions based on the grids mentioned above, as shown in **Table 2** and **Fig. 7.**

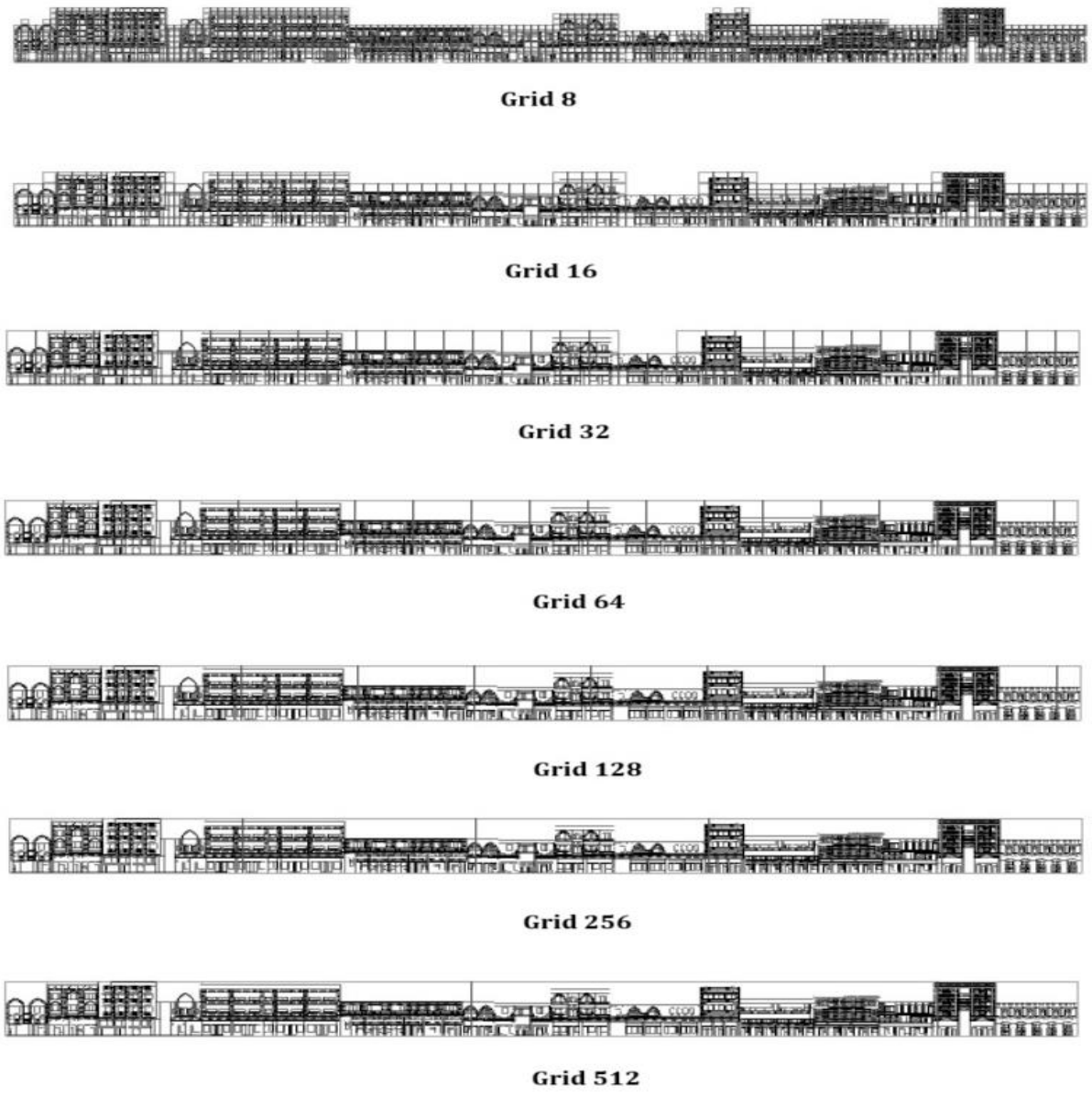

Figure 7. Analysis panorama of zone B in grids (8,16,32,64,128,256,512)

Table 2. Fractal dimensions of zone B according to the grids

Zone B	
Grid	**Fractal dimension**
8,16	1.8805
16,32	1.5717
32,64	1.5203
64,128	1.926
128,256	1
256,512	0.737

Upon reviewing the initial findings, an analysis was conducted on both sides of Al-Mutanabbi Street to compare the fractional dimension results. This comparison was achieved by calculating the correlation coefficient (Correl) using the Excel program. It's important to note that the correlation coefficient values range from -1.0 to 1.0. If the calculated correlation exceeds 1.0 or falls below -1.0, an error has occurred in the analysis. A correlation of -1.0 signifies a perfect negative correlation, while a correlation of 1.0 indicates a perfect positive correlation **(Srivastav, 2017).** After comparing the fractional dimensions of both sides of Al-Mutanabbi Street, we found that the correlation coefficient is 0.919862. This indicates a high level of harmony in the formal characteristics, such as durability and cohesion between parts of the panorama, also diversity compared to the unity among the elements in different parts of the panorama, and richness in the elements across the panorama's parts. as shown in **Fig. 8**.

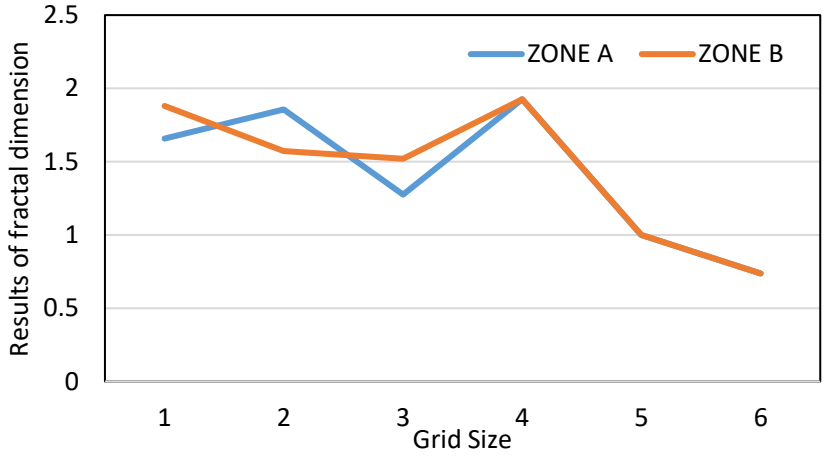

Figure 8. A chart showing the degree of harmony between Zone A and Zone B in Al-Mutanabbi Street

- The second level: involves the categorization of buildings into groups based on the horizontal plan of zone A. The groups are separated by side paths, as illustrated in **Fig. 3**, with each group comprising three buildings. The analysis involves formulating the plans in AutoCAD, analyzing them in ImageJ, and applying the box-counting method to each group. The analysis process includes selecting the same network sizes (8,16), (16,32), (32,64), (64,128), (128,256), and (256,512).

Zone A was subdivided into 5 groups **Fig. 9**, with each group comprising 3 buildings. The analysis was conducted for each group based on the provided networks, and the results of the fractional dimension for each group are presented in **Table 3.** Subsequently, the groups

were compared to each other using the fractional dimension to assess the level of variation and coherence among the five groups as shown in **Table 4** and **Fig. 10.**

Table 3. Fractal dimension for each group in zone A.

Zone A					
Grid	**G1**	**G2**	**G3**	**G4**	**G5**
8,16	1.5513	1.5595	1.596	1.8032	1.8302
16,32	1.5907	1.6865	1.636	1.8894	1.9293
32,64	1.8377	1.8451	1.7697	1.8433	2
64,128	1.6004	1.703	1.6464	1.9175	1.9175
128,256	1.6323	1.5194	1.6167	1.848	0.848
256,512	1.737	1.3219	1.3219	0.737	0.737

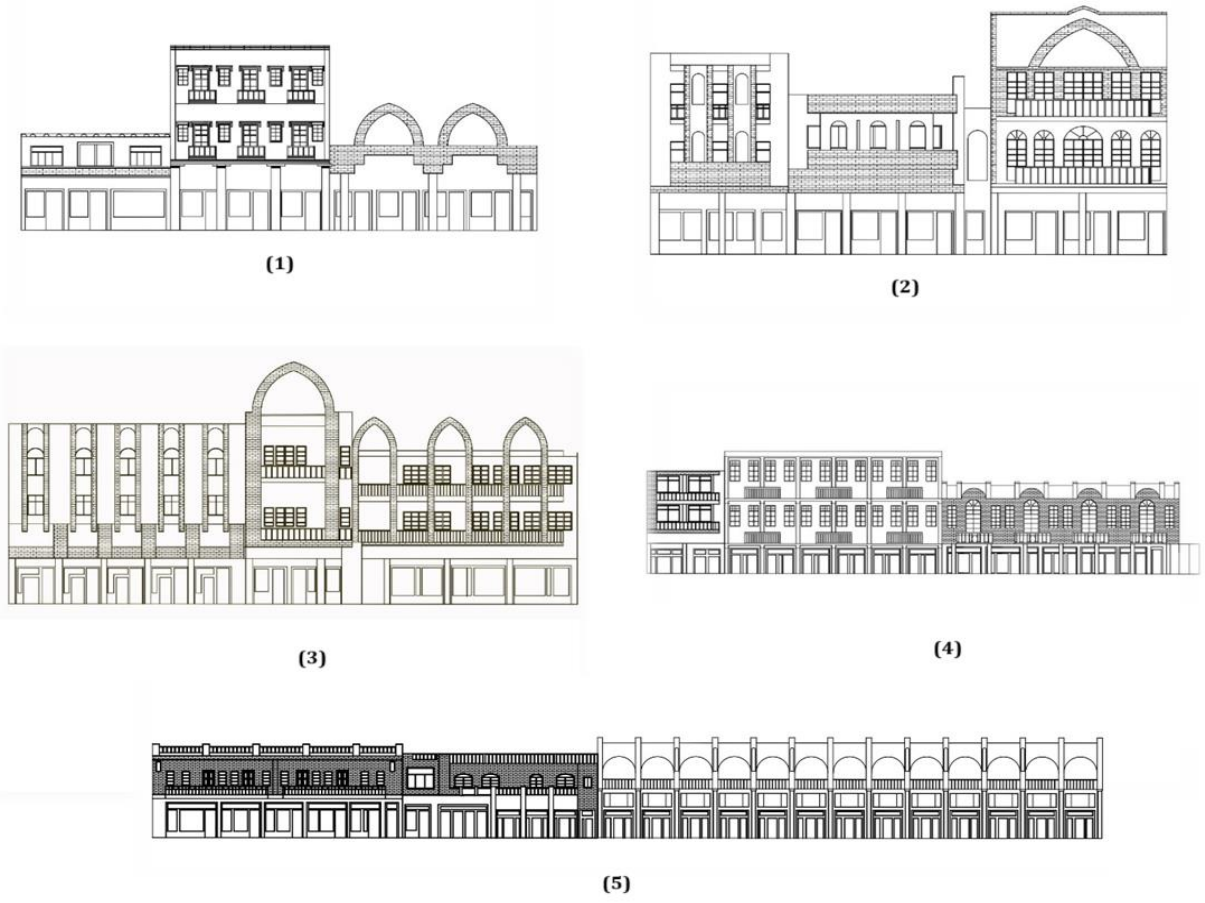

Figure 9. Zone A subdivision to 5 groups.

We determined the correlation coefficient value for each group in zone A to thoroughly evaluate the level of harmony between the groups, as shown in **Table 4.** Next, we made a comprehensive comparison of the correlation coefficient value for each group in zone A with the correlation coefficient values of the overall panorama, as shown in **Table 5.**

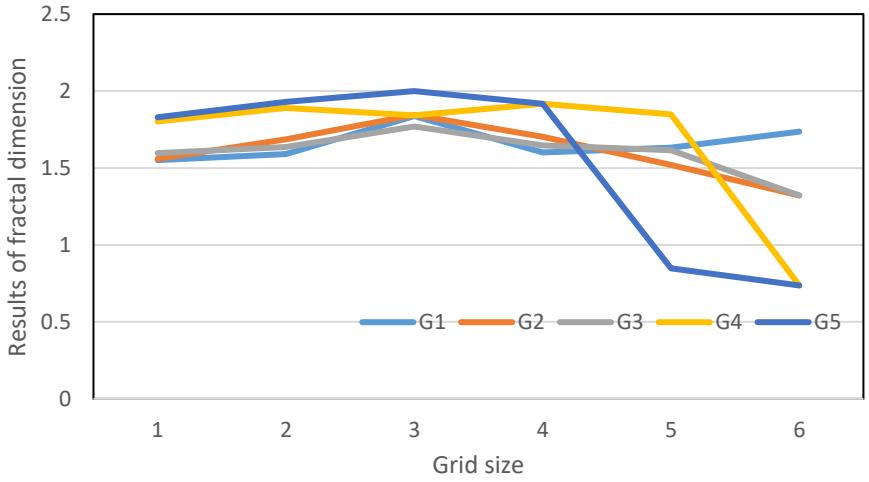

Figure. 10 A graph showing the degree of harmony between the five groups (G1-G5) of zone A.

Table 4. The correlation coefficient value between the groups in zone A.

Groups	Correl value between groups
G1-G2	0.17095138
G1-G3	0.042820189
G1-G4	-0.363292226
G1-G5	-0.132439302
G2-G3	0.93828204
G2-G4	0.784860295
G2-G5	0.855106559
G3-G4	0.910931644
G3-G5	0.73812771
G4-G5	0.685232794

Table 5. The comparison of correlation coefficient values between the groups of zone A and the overall panorama

Between panoramas and groups	Correl value between panoramas and groups
Panorama - G1	-0.58583
Panorama - G2	0.616559
Panorama - G3	0.549261
Panorama - G4	0.711201
Panorama - G5	0.850977

4.2 Result Comparison

By comparing the results of groups in Zone A, we can clearly observe the property of visual coherence among adjacent facades. This coherence, referred to as robustness, is assessed by evaluating axial symmetry and the similarity of the facade elements. Additionally, we can identify a balance between diversity and unity regarding the formal characteristics of these elements, which is measured by the variety of facade designs, their heights, and their proportions within a cohesive and interconnected system. Furthermore, we see a diversity in the urban landscape at the component level, characterized by a rhythmic gradation and similarity among the elements, all organized within a well-proportioned system of active building fronts.

By comparing the results of panorama with the results of elements in Zone A, we observe a characteristic of harmony with the human scale known as Personalization. This can be measured by the consistent rhythm in the skyline created by the façades that make up the whole. Additionally, there is an integration within the urban scene at the level of the components, referred to as the Integrative Facade. This is achieved by cohesively designing the façades in a tight visual system through a repeated rhythm. While the street shows a wide range of elements and details, analysis using fractal geometry tools exposed a unifying structure that contributes to the creation of a harmonious urban landscape. This finding brings into line the concept of unity within diversity, emphasizing the integration of diverse elements to achieve visual consistency. The box-counting method was utilized to quantify the level of variation in the harmony of the components. The findings indicate that fractal dimensions offer precise assessments of the levels of harmony and complexity in urban development, enhancing our comprehension of the formation and evolution of traditional urban structures.

Despite the diversity of the street's elements and architectural details, fractal geometry has proven that there is a unified structure that organizes this diversity; where different elements blend to create a cohesive urban landscape. This concept is known as "diversity within unity," which achieves visual harmony that allows diverse forms to merge into a single structure, giving the urban environment visual richness without compromising its overall harmony.

5. CONCLUSIONS

- Fractal geometry helps to uncover how various aspects of urban structure blend together seamlessly. The research demonstrated that the classic street design exhibits self-similarity in the arrangement of its architectural elements, contributing to a sense of harmony between the buildings and different segments of the thoroughfare.
- While the street shows a wide range of elements and details, analysis using fractal geometry tools exposed a unifying structure that contributes to the creation of a harmonious urban landscape. This finding bring into line the concept of unity within diversity, emphasizing the integration of diverse elements to achieve visual consistency.
- The significance of joining fractal properties into new urban design to preserve local identity, reflect local character and support cultural continuity.
- Fractal geometry plays a vital role in analyzing and evaluating the balance between several components in urban spaces. By using concepts such as fractal dimension and self-similarity, architects and urban planners can understand how to structure and arrange elements in traditional settings to achieve coherence and harmony.
- Fractal geometry used mechanisms such as repetition, hierarchy, symmetry, and similarity; these mechanisms helped to achieve an integrated unity in the architectural system. These methods work to link the different parts of the design within a complex structure, where all parts share formal characteristics that contribute to cohesion and harmony, making them appear as if they are part of a single integrated and harmonious architectural system.

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Credit Authorship Contribution Statement

Aya A. Al-Dabbagh: Writing – review & editing, Writing – original draft, validation, software
Khalid J. Aldeen Ismail: Writing –review & editing, Methodology

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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أدوات الهندسة الكسيرية في دراسة الخصائص الشكلية في البنية الحضرية لشارع المتنبي التقليدي في بغداد

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الخلاصة

يهتم البحث بدراسة درجة الانسجام في الخصائص الشكلية بين مكونات البيئة الحضرية في الزقاق التقليدي البغدادي ابتداءا من الجزء الى الاجزاء ومن ثم الكل، اذ تتسم البيئة الحضرية العربية التقليدية بشكل عام، والازقة البغدادية بشكل خاص وفق دراسات كثيرة بالوحدة والتماسك في بنيها الحضرية مع تنوع المشهد الحضري. في الجزء النظري من الدراسة يتم التركيز على الخصائص البصرية للبيئة الحضرية التقليدية ضمن إطار مفهوم التنوع ضمن الوحدة، وذلك من خلال بعض الدراسات المتخصصة في هذا المجال. في حين ان الجزء التطبيقي يهتم بتوظيف ادوات الهندسة الكسرية (طريقة البعد الصندوقي) في قياس مدى التباين في درجة الانسجام بين اجزاء البيئة الحضرية ابتداءا من الجزء والاجزاء وصولا للكل الذي يمثل البانوراما على جهتي المسار في الزقاق. تهدف هذه الدراسة الى ابراز اهم سمات الازقة التقليدية من خلال خصائصها البصرية الكامنة في بنيتها التركيبية الحضرية التقليدية، ان ذلك يعد عاملا مهما في توظيف تلك الخصائص في التصاميم الحضرية الجديدة حفاظا على الهوية المحلية. أخذ البحث في الاعتبار التأثيرات التاريخية والاجتماعية والثقافية على التصميم الحضري في شارع المتنبي. تكمن مشكلة البحث في عدم وجود دراسات حول الهندسة الكسيرية كأداة تحليلية للمصممين لتحقيق خصائص شكلية محددة، مثل التناغم بين الأجزاء والكل، وخاصة في سياق المسارات التقليدية. وكشفت النتائج أن هذه التأثيرات تؤثر بشكل كبير على الإطار الحضري وتعزز التماسك بين العناصر المختلفة.

الكلمات المفتاحية: الهندسة الكسرية، البيئة الحضرية، شارع المتنبي، الانسجام، الوحدة.